

Prospects on constraining ΔG from inclusive jet production in polarized pp collisions at RHIC in 2003

B. Surrow for the STAR Collaboration¹

*Brookhaven National Laboratory
Department of Physics
Upton, NY 11973-5000
USA*

Abstract. The anticipated increase in luminosity and polarization for the RHIC spin run in 2003 together with the installation of spin rotators at the STAR interaction region will allow the first measurement of A_{LL} in inclusive jet production at $\sqrt{s} = 200$ GeV. This data should provide hints of the gluon polarization, $\Delta G/G$, of the proton. In the long-term, the determination of the gluon polarization of the proton will be made through prompt-photon production and photon-jet coincidences. Other possibilities include di-jet production and heavy flavor production.

The measurement of A_{LL} , the expected event rates, and simulation results based on the anticipated RHIC performance in 2003 will be described together with a discussion of various systematic error sources.

INTRODUCTION

The spin of elementary particles is as fundamental to their nature as the mass. The proton is a fermion of $J = 1/2$. The proton spin is understood to be made up of contributions arising from the quark spin, the gluon spin, and orbital angular momentum. The fundamental question in this regard is how the proton spin is distributed among those contributions. It was found in polarized lepton-nucleon experiments that only about 1/3 of the proton spin is carried by quarks and anti-quarks, contrary to the expectation of the constituent quark model that the proton spin would be carried predominantly by its three valence quarks. A significant fraction of the proton spin must therefore be carried by gluons and orbital angular momentum. The role of the gluons in making up the missing proton spin is currently only very poorly constrained from scaling violations in deep-inelastic scattering fixed-target experiments. A need for a new generation of experiments to explore the spin structure of the proton is clearly apparent. The current spin physics effort at RHIC at BNL focuses on the collision of polarized protons to gain a deeper understanding of the spin structure of the proton in a new, previously unexplored territory. The first polarized proton run from December 2001 until January 2002 is the beginning of a multi-year experimental program which aims to address a

¹ For the full author list and acknowledgments, see appendix to the proceedings.

variety of topics related to the spin structure of the proton. A recent review of the RHIC spin program can be found in [1].

The measurement of the double longitudinal spin asymmetry, A_{LL} , for photon production allows the extraction of the gluon polarization, $\Delta G/G$. In LO QCD employing factorization of the underlying hard process, the asymmetry measured for $\vec{p} + \vec{p} \rightarrow \gamma + \text{jet} + X$ is represented as: $A_{LL} = \frac{\Delta G(x_g)}{G(x_g)} \cdot A_1^p(x_q) \cdot \hat{a}(g + q \rightarrow \gamma + q)$. The ratio of the polarized and unpolarized structure functions, $A_1^p(x_q)$, is measured in polarized deep-inelastic scattering and $\hat{a}(g + q \rightarrow \gamma + q)$ is calculated in pQCD. Hence a measurement of A_{LL} for prompt photons detected in coincidence with the away-side quark-jet allows an extraction of the gluon polarization $\Delta G(x_g)/G(x_g)$.

THE POLARIZED PROTON COLLIDER RHIC

The first collisions of polarized protons occurred in December 2001, ushering in a new era to complement the ongoing relativistic heavy-ion program. RHIC is the first accelerator to accelerate and collide polarized protons, ultimately at high luminosity, and at a center-of-mass energy of up to 500 GeV. An overview of the polarized proton collider RHIC can be found in [4].

The first polarized proton run at RHIC was carried out at $\sqrt{s} = 200$ GeV. A transverse polarization of about 0.2 was achieved at the injection energy of 24.6 GeV and was approximately maintained when the proton beams were accelerated to 100 GeV.

The collision of longitudinal polarized protons at $\sqrt{s} = 200$ GeV is foreseen for the first time at RHIC in 2003 with the installation of spin rotators at the STAR and PHENIX interaction regions. The anticipated polarization is about 0.4 and the instantaneous luminosity of $1 \cdot 10^{31} \text{ s}^{-1} \text{ cm}^{-2}$ is an order of magnitude larger compared to the first polarized proton run in 2002. The expected integrated luminosity at the STAR experiment for longitudinal polarized protons amounts to approximately 3 pb^{-1} . Those RHIC performance expectations on polarization and luminosity serve as the basis for simulations of A_{LL} in inclusive jet production.

THE STAR EXPERIMENT

A detailed description of the STAR experiment can be found in [5]. The STAR experiment was upgraded for the polarized proton program with the installation of a beam-beam counter (BBC) [6] and a forward-pion detector (FPD) [7] prior to the first polarized proton run of transverse polarized protons. Both components will play a crucial role in measuring A_{LL} . The BBC provides the principal relative luminosity measurement. An upgraded FPD detector system will be used to tune the spin rotators at the STAR interaction region [8].

Installation of the STAR electromagnetic calorimeters [5] is partially complete. The STAR barrel electromagnetic calorimeter has been completed for $0 < \eta < 1$ and $\Delta\phi = 2\pi$ for the RHIC run in 2003. Part of the STAR endcap electromagnetic calorimeter has been installed. In subsequent years, it is expected that the barrel electromag-

netic calorimeter will have complete azimuthal coverage for the interval $-1 < \eta < 1$. The endcap electromagnetic calorimeter will provide complete azimuthal coverage for $1.09 < \eta < 2$. Both systems will be crucial to study inclusive jet production and ultimately prompt-photon production and photon-jet coincidences.

The simulations below are based on the partial calorimeter coverage in 2003 of $0 < \eta < 1$ and $\Delta\phi = 2\pi$.

INCLUSIVE JET PRODUCTION

Besides the golden channel ($\vec{p} + \vec{p} \rightarrow \gamma + \text{jet} + X$) to measure ΔG , inclusive jet production provides another way of constraining ΔG accessible in the 2003 run. The sensitivity to ΔG arises from gluon-initiated processes such as: $gg \rightarrow gg$ and $qg \rightarrow qg$. Jet production also includes the $qq^{(\prime)} \rightarrow qq^{(\prime)}$ processes.

The yield for the anticipated condition in 2003 for 10 days of running at an efficiency of 33% has been estimated from a PYTHIA simulation. For $p_T = 5 - 10 \text{ GeV}$, $1 \cdot 10^6$ jets are expected to be recorded. This number reduces to $1 \cdot 10^3$ for $p_T = 30 - 35 \text{ GeV}$.

Figure 1 shows the result of a PYTHIA-based simulation for A_{LL} in inclusive jet production including trigger and jet reconstruction efficiency effects.

Besides the PYTHIA event generation, the response of electromagnetic (e.g. photons) and hadronic energy deposition in the barrel electromagnetic calorimeter has been separately accounted for. In addition, polarization effects are added after the PYTHIA event generation using separate polarized and unpolarized structure functions and the partonic, process-dependent LO pQCD results for \hat{a}_{LL} .

A jet trigger requiring $E_T > 5 \text{ GeV}$ for a $(\Delta\eta = 1) \times (\Delta\phi = 1)$ patch of the barrel electromagnetic calorimeter has been applied. Jets were reconstructed using a cone algorithm with a seed of 1 GeV and a radius of $R = 0.7$. The result of two simulations are shown using two different input parameterizations for ΔG , GRSV-std and GRSV-max [2]. The latter reflects the limiting case of ΔG [3].

The reconstructed values for A_{LL} for the two different ΔG parameterizations reveal a different dependence on the measured jet transverse energy between approximately $5 - 15 \text{ GeV}$. It is the region of small values in the measured jet transverse energy where the sensitivity to ΔG is expected to be dominant.

Beyond a measured jet transverse energy of 15 GeV , the expected uncertainty does not permit drawing any further conclusions on discriminating different ΔG parameterizations under the conditions expected for 2003.

A clear sensitivity in A_{LL} for ΔG has been also established from a NLO calculation using two different input parameterizations (GRSV-std and GRSV-max) based on the anticipated RHIC performance [9]. No detector effects have been included in those studies.

Besides discussing a possible sensitivity to ΔG for inclusive jet production during the RHIC run in 2003, a major emphasis with the first measurement of A_{LL} will be the understanding of various systematic error sources which contribute to the measurement of A_{LL} and thus ultimately to the extraction of ΔG .

Systematic errors in the measurement of A_{LL} arise from various uncertainties. The

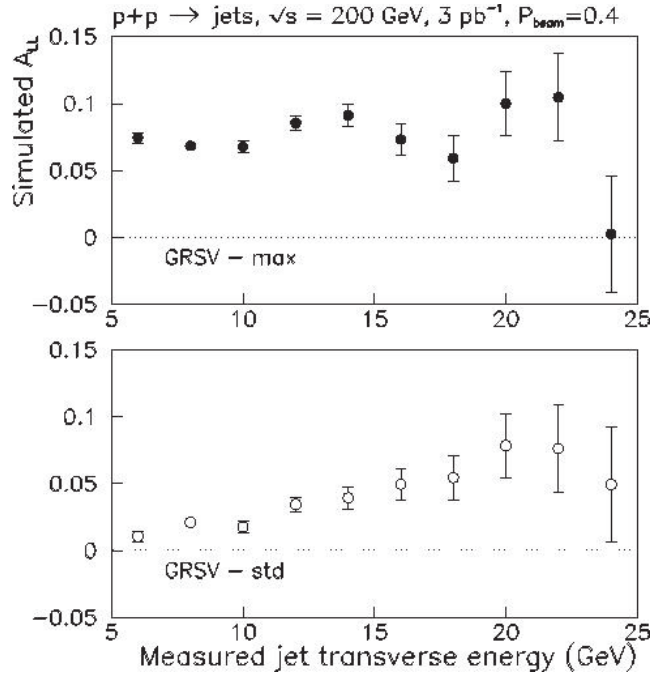


FIGURE 1. A_{LL} from a PYTHIA-based simulation for inclusive jet production including trigger and jet reconstruction efficiency effects. Only statistical errors are shown.

absolute polarization uncertainty at injection is known at present to about 20%. The analyzing power of the RHIC CNI polarimeter [10] at full beam energy has not been measured yet. Ultimately, the RHIC beam polarization will be determined from a polarized gas jet target experiment to about 5%. This will not be available for the first RHIC run of longitudinal polarized protons [11]. Therefore other means have to be explored such as the RHIC down-ramping development [12] to estimate the beam polarization at full beam energy by constraining the analyzing power of the RHIC CNI polarimeter at full energy.

The measurement of the relative luminosity will be crucial in the measurement of A_{LL} . More details can be found in [6].

Differences in the fragmentation for quark and gluon jets could lead to a possible trigger bias. It is therefore important to employ different jet triggers to see if those changes on the trigger level can be accounted for by simulations.

The collision of longitudinal polarized protons at $\sqrt{s} = 200$ GeV is foreseen for the first time at RHIC in 2003 with the installation of spin rotators at the STAR interaction region. It is planned to determine the operating point of the spin rotator magnets by minimizing left/right and up/down spin-dependent asymmetries with the upgraded FPD detector system [8].

Figure 2 shows preliminary results of uncorrected distributions for jet production obtained during the first run of transverse polarized protons in 2002 at $\sqrt{s} = 200$ GeV. A cone jet finder for charged particles employing the STAR TPC only has been used with: $R = 0.7$, seed > 1 GeV, $E_T > 5$ GeV and $|\eta^{jet}| < 0.7$. The uncorrected transverse energy distribution and the difference in azimuth angle for a di-jet sample is shown. This first

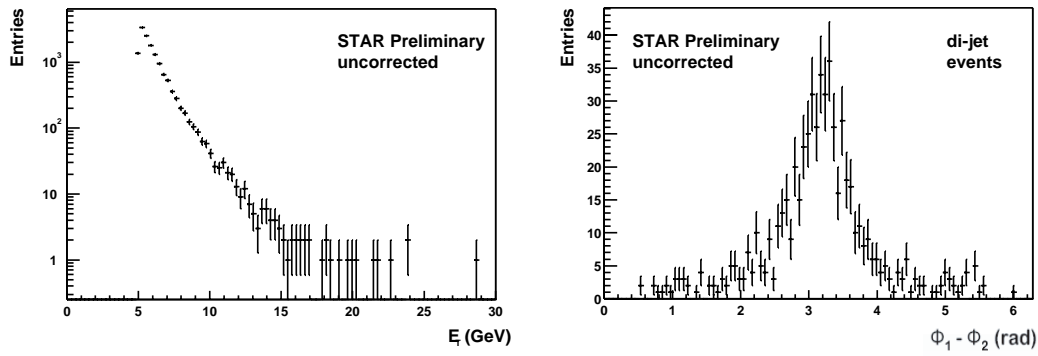


FIGURE 2. Preliminary results of uncorrected distributions for jet production obtained during the first run of transverse polarized protons in 2002 at $\sqrt{s} = 200$ GeV.

look at jet production is quite encouraging for the STAR spin program in 2003.

SUMMARY AND OUTLOOK

The collision of longitudinal polarized protons at $\sqrt{s} = 200$ GeV is foreseen for the first time at RHIC in 2003 with the installation of spin rotators at the STAR interaction region.

The result of a PYTHIA-based simulation including detector effects and anticipated 2003 operating conditions indicated that STAR would be able to measure A_{LL} as a function of the jet transverse energy for the first time. Various systematic errors sources will have to be carefully understood in order that, at a later stage, extractions of ΔG can be reliably performed.

REFERENCES

1. G. Bunce et al., *Ann. Rev. Nucl. Part. Sci.* 50 (2000) 525.
2. M. Glück, E. Reya, M. Stratmann and W. Vogelsang, *Phys. Rev. D* 63 (2001) 094005.
3. M. Glück, E. Reya, and A. Vogt, *Eur.Phys.J. C* 5 (1998) 461.
4. H. Huang, *these proceedings*.
5. STAR Collaboration, *Nucl.Instrum.Meth.* to be published (Special volume edition).
6. J. Koryluk, *these proceedings*.
7. G. Rakness, *these proceedings*.
8. A. Ogawa, *these proceedings*.
9. W. Vogelsang, *private communications*.
10. O. Jinnouchi, *these proceedings*.
11. A. Bravar, *these proceedings*.
12. H. Spinka, *these proceedings*.